

## REMARKS

In response to the requirement that a species be elected, the applicant elects the embodiment of Figs. 5-7 and lists claims 1 and 11-13 as reading on the elected species, with traverse.

Since the present application is the national stage application of a Patent Cooperation Treaty application, the provisions of PCT Rule 13.2 contain the relevant provisions and 35 U.S.C. §121 is not applicable. Under the ADMINISTRATIVE INSTRUCTIONS UNDER THE PCT, page AI-58, which is available as Annex B to APPENDIX T of the MPEP

"If the independent claims avoid the prior art and satisfy the requirement of unity of invention, no problem of lack of unity arises in respect of any claims that depend on the independent claims. In particular, it does not matter if a dependent claim itself contains a further invention. Equally, no problem arises in the case of a genus/species situation where the genus claim avoids the prior art."

In the present application the Examiner has argued that generic claim 1 is unpatentable over Horii et al. (Horii). Claim 1 has been amended by combining claims 1 and 3. Amended claim 1 now points out that the pressurizing station (16) has, as pumping unit, one or more pumps (22), each equipped with a continuous electric-electronic inverter (38, 38a) for the regulation of the rotation rate, said pumps (22) being automatically operated by an automatic measurement and control system (41, 42). This feature is not described or suggested by Horii and for this reason, it is requested that the species requirement be withdrawn.

At page 3 of the Office Action, the Examiner rejected claims 1-13 under 35 U.S.C. §112, second paragraph, for failing to particularly point out and distinctly claim the subject matter that the applicant regards as the invention.

Reconsideration is requested in view of this Amendment.

Claim 1 has been amended to delete the terms "lifting" and "preferably". The Examiner objected to the usage of the term "inverter" in original claim 3. This term is used in the art to describe variable-frequency drives as shown by the attached copy of the section on "Inverters" from Wikipedia, page 2, downloaded from [http://en.Wikipedia.org/wiki/Inverter\(electrical\)](http://en.Wikipedia.org/wiki/Inverter(electrical)). In the context of original claim 3, the term "inverter" is not indefinite.

As noted above, the substance of claim 3 has been included in amended claim 1 with the modification that points out that the continuous electric-electronic inverter (38, 38a) is "for the regulation of the rotation rate". This amendment is supported by the specification at page 12, lines 4-7 and page 25, lines 8-9. Claim 4 has been amended to recite that chamber (51) is on or in duct 14 and the expression "in a transit canalization" has been deleted. The amended text of claim 4 points out that the chamber (51) is positioned horizontally or vertically "on or in duct (14)". The mounting of chamber (51) on duct (14) is shown in Fig. 1 and the mounting of chamber (51) in duct (14) is shown in Fig. 4. In claims 5 and 7, the term "regime" been deleted so that the amended claim has a plain and unambiguous meaning. Claim 10 has been amended to delete the term "envisaged" to avoid the objection that this term is indefinite.

Claims 7 and 8 have been canceled in response to the rejection of thee claims under 35 U.S.C. §112, first and second paragraphs.

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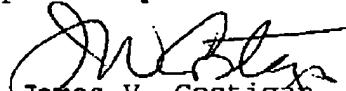
Claims 1, 2 and 10 were rejected under 35 U.S.C. §102(b) as being anticipated by Horii.

Reconsideration is requested.

As noted above, the substance of claims 1 and 3 have combined. The Horii system does not utilize a "pressurizing station (16) has, as pumping unit, one or more pumps (22), each equipped with a continuous electric-electronic inverter (38, 38a) for the regulation of the rotation rate, said pumps (22) being automatically operated by an automatic measurement and control system (41, 42)" as pointed out in original claim 3. All of the claims in the application are now directly or indirectly dependent on claim 1 and in view of the amendment of claim 1, it is requested that the rejection for lack of novelty be withdrawn.

An early and favorable action is earnestly solicited.

Respectfully submitted,



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# Inverter (electrical)

From Wikipedia, the free encyclopedia

An inverter is an electrical device that converts direct current (DC) to alternating current (AC); the resulting AC can be at any required voltage and frequency with the use of appropriate transformers, switching, and control circuits.

Static inverters have no moving parts and are used in a wide range of applications, from small switching power supplies in computers, to large electric utility high-voltage direct current applications that transport bulk power. Inverters are commonly used to supply AC power from DC sources such as solar panels or batteries.

The electrical inverter is a high-power electronic oscillator. It is so named because early mechanical AC to DC converters were made to work in reverse, and thus were "inverted", to convert DC to AC.

The inverter performs the opposite function of a rectifier.

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## Applications

### DC power source utilization

An inverter converts the DC electricity from sources such

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as batteries, solar panels, or fuel cells to AC electricity. The electricity can be at any required voltage; in particular it can operate AC equipment designed for mains operation, or rectified to produce DC at any desired voltage.

Grid tie inverters can feed energy back into the distribution network because they produce alternating current with the same wave shape and frequency as supplied by the distribution system. They can also switch off automatically in the event of a blackout.

Micro-inverters convert direct current from individual solar panels into alternating current for the electric grid.<sup>[1]</sup>

### Uninterruptible power supplies

An uninterruptible power supply (UPS) uses batteries and an inverter to supply AC power when main power is not available. When main power is restored, a rectifier is used to supply DC power to recharge the batteries.

### Induction heating

Inverters convert low frequency main AC power to a higher frequency for use in induction heating. To do this, AC power is first rectified to provide DC power. The inverter then changes the DC power to high frequency AC power.

### HVDC power transmission

With HVDC power transmission, AC power is rectified and high voltage DC power is transmitted to another location. At the receiving location, an inverter in a static inverter plant converts the power back to AC.

### Variable-frequency drives

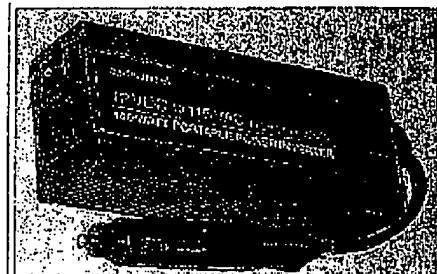
A variable-frequency drive controls the operating speed of an AC motor by controlling the frequency and voltage of the power supplied to the motor. An inverter provides the controlled power. In most cases, the variable-frequency drive includes a rectifier so that DC power for the inverter can be provided from main AC power. Since an inverter is the key component, variable-frequency drives are sometimes called inverter drives or just inverters.

### Electric vehicle drives

Adjustable speed motor control inverters are currently used to power the traction motor in some electric locomotives and diesel-electric locomotives as well as some battery electric vehicles and hybrid electric highway vehicles such as the Toyota Prius. Various improvements in inverter technology are being developed specifically for electric vehicle applications.<sup>[2]</sup> In vehicles with regenerative braking, the inverter also takes power from the motor (now acting as a generator) and stores it in the batteries.

### Air Conditioning

An air conditioner bearing the inverter tag uses a variable-frequency drive to control the speed of the



Inverter designed to provide 115 VAC from the 12 VDC source provided in an automobile. The unit shown provides up to 1.2 Amps of alternating current, or just enough to power two sixty watt light bulbs.

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motor and thus the compressor.

### The general case

A transformer allows AC power to be converted to any desired voltage, but at the same frequency. Inverters, plus rectifiers for DC, can be designed to convert from any voltage, AC or DC, to any other voltage, also AC or DC, at any desired frequency. The output power can never exceed the input power, but efficiencies can be high, with a small proportion of the power dissipated as waste heat.

### Warnings

Some low power inverters have a warning not to use conventional fluorescent lighting. This is due to the power correction capacitor connected in parallel with the lamp, removing the capacitor will fix the problem. What may not be known is that in dual lamp fittings the capacitor is connected in series with the second lamp removing the problem as well as the stroboscopic effect caused by the mains frequency.

## Circuit description

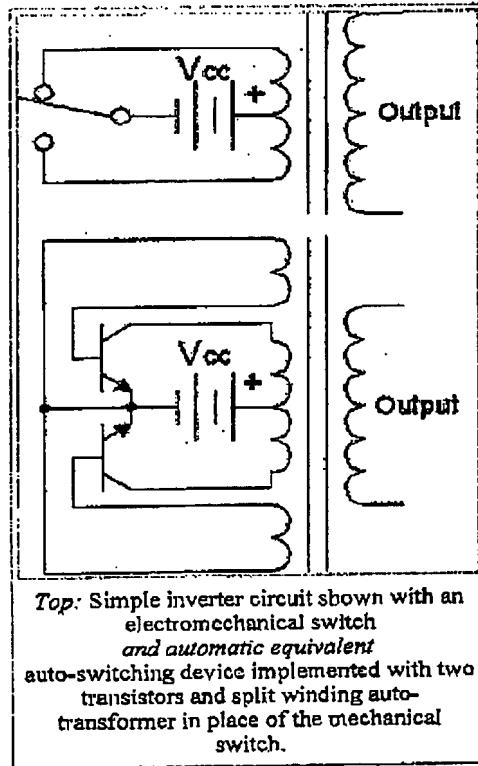
### Basic designs

In one simple inverter circuit, DC power is connected to a Transformer through the centre tap of the primary winding. A switch is rapidly switched back and forth to allow current to flow back to the DC source following two alternate paths through one end of the primary winding and then the other. The alternation of the direction of current in the primary winding of the transformer produces alternating current (AC) in the secondary circuit.

The electromechanical version of the switching device includes two stationary contacts and a spring supported moving contact. The spring holds the movable contact against one of the stationary contacts and an electromagnet pulls the movable contact to the opposite stationary contact. The current in the electromagnet is interrupted by the action of the switch so that the switch continually switches rapidly back and forth. This type of electromechanical inverter switch, called a vibrator or buzzer, was once used in vacuum tube automobile radios. A similar mechanism has been used in door bells, buzzers and tattoo guns.

As they became available from early 1970s, transistors and various other types of semiconductor switches have been incorporated into inverter circuit designs.

### Output waveforms



The switch in the simple inverter described above produces a square voltage waveform as opposed to the sinusoidal waveform that is the usual waveform of an AC power supply. Using Fourier analysis, periodic waveforms are represented as the sum of an infinite series of sine waves. The sine wave that has the same frequency as the original waveform is called the fundamental component. The other sine waves, called *harmonics*, that are included in the series have frequencies that are integral multiples of the fundamental frequency.

The quality of the inverter output waveform can be expressed by using the Fourier analysis data to calculate the total harmonic distortion (THD). The total harmonic distortion is the square root of the sum of the squares of the harmonic voltages divided by the fundamental voltage:

$$\text{THD} = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + \dots + V_n^2}}{V_1}$$

The quality of output waveform that is needed from an inverter depends on the characteristics of the connected load. Some loads need a nearly perfect sine wave voltage supply in order to work properly. Other loads may work quite well with a square wave voltage.

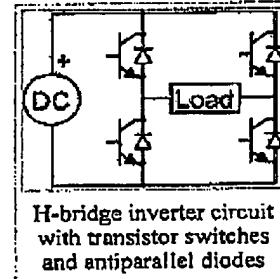
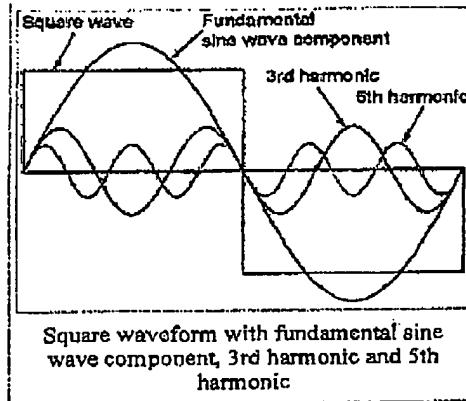
### Advanced designs

There are many different power circuit topologies and control strategies used in inverter designs. Different design approaches address various issues that may be more or less important depending on the way that the inverter is intended to be used.

The issue of waveform quality can be addressed in many ways. Capacitors and inductors can be used to filter the waveform. If the design includes a transformer, filtering can be applied to the primary or the secondary side of the transformer or to both sides. Low-pass filters are applied to allow the fundamental component of the waveform to pass to the output while limiting the passage of the harmonic components. If the inverter is designed to provide power at a fixed frequency, a resonant filter can be used. For an adjustable frequency inverter, the filter must be tuned to a frequency that is above the maximum fundamental frequency.

Since most loads contain inductance, feedback rectifiers or antiparallel diodes are often connected across each semiconductor switch to provide a path for the peak inductive load current when the switch is turned off. The antiparallel diodes are somewhat similar to the *freewheeling diodes* used in AC/DC converter circuits.

Fourier analysis reveals that a waveform, like a square wave, that is antisymmetrical about the 180 degree point contains only odd harmonics, the 3rd, 5th, 7th etc. Waveforms that have steps of certain widths and heights eliminate or "cancel" additional harmonics. For example, by inserting a zero-voltage step between the positive and negative sections of the square-wave, all of the harmonics that are divisible by three can be eliminated. That leaves only the 5th, 7th, 11th, 13th etc. The required



H-bridge inverter circuit with transistor switches and antiparallel diodes

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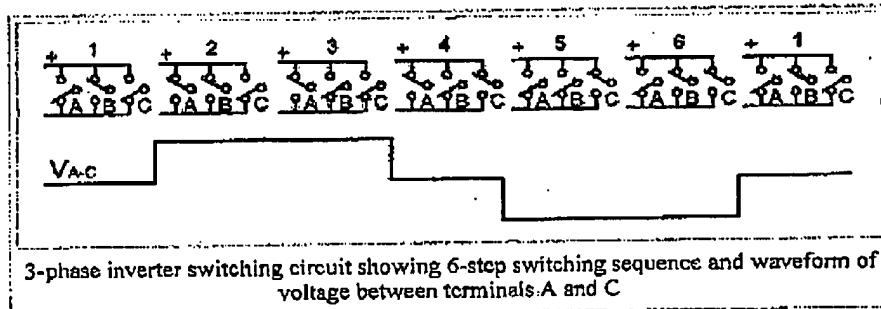
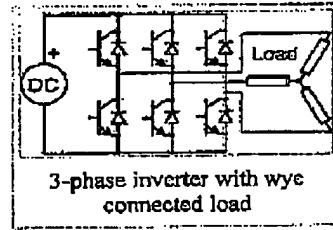
width of the steps is one third of the period for each of the positive and negative voltage steps and one sixth of the period for each of the zero-voltage steps.

Changing the square wave as described above is an example of pulse-width modulation (PWM). Modulating, or regulating the width of a square-wave pulse is often used as a method of regulating or adjusting an inverter's output voltage. When voltage control is not required, a fixed pulse width can be selected to reduce or eliminate selected harmonics. Harmonic elimination techniques are generally applied to the lowest harmonics because filtering is more effective at high frequencies than at low frequencies. *Multiple pulse-width* or *carrier based* PWM control schemes produce waveforms that are composed of many narrow pulses. The frequency represented by the number of narrow pulses per second is called the *switching frequency* or *carrier frequency*. These control schemes are often used in variable-frequency motor control inverters because they allow a wide range of output voltage and frequency adjustment while also improving the quality of the waveform.

Multilevel inverters provide another approach to harmonic cancellation. Multilevel inverters provide an output waveform that exhibits multiple steps at several voltage levels. For example, it is possible to produce a more sinusoidal wave by having split-rail direct current inputs at two voltages, or positive and negative inputs with a central ground. By connecting the inverter output terminals in sequence between the positive rail and ground, the positive rail and the negative rail, the ground rail and the negative rail, then both to the ground rail, a stepped waveform is generated at the inverter output. This is an example of a three level inverter: the two voltages and ground. [3]

### Three phase inverters

Three-phase inverters are used for variable-frequency drive applications and for high power applications such as HVDC power transmission. A basic three-phase inverter consists of three single-phase inverter switches each connected to one of the three load terminals. For the most basic control scheme, the operation of the three switches is coordinated so that one switch operates at each 60 degree point of the fundamental output waveform. This creates a line-to-line output waveform that has six steps. The six-step waveform has a zero-voltage step between the positive and negative sections of the square-wave such that the harmonics that are multiples of three are eliminated as described above. When carrier-based PWM techniques are applied to six-step waveforms, the basic overall shape, or *envelope*, of the waveform is retained so that the 3rd harmonic and its multiples are cancelled.



To construct inverters with higher power ratings, two six-step three-phase inverters can be connected in parallel for a higher current rating or in series for a higher voltage rating. In either case, the output waveforms are phase shifted to obtain a 12-step waveform. If additional inverters are combined, an

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18-step inverter is obtained with three inverters etc. Although inverters are usually combined for the purpose of achieving increased voltage or current ratings, the quality of the waveform is improved as well.

## History

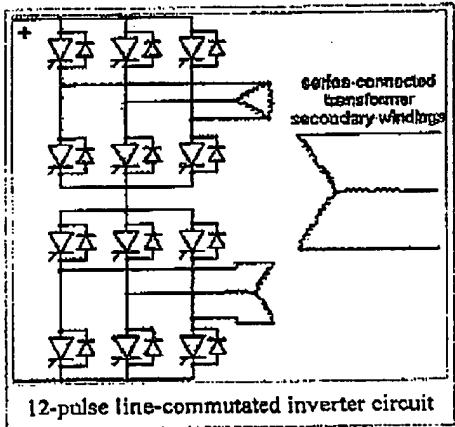
### Early inverters

From the late nineteenth century through the middle of the twentieth century, DC-to-AC power conversion was accomplished using rotary converters or motor-generator sets (M-G sets). In the early twentieth century, vacuum tubes and gas filled tubes began to be used as switches in inverter circuits. The most widely used type of tube was the thyratron.

The origins of electromechanical inverters explain the source of the term *inverter*. Early AC-to-DC converters used an induction or synchronous AC motor direct-connected to a generator (dynamo) so that the generator's commutator reversed its connections at exactly the right moments to produce DC. A later development is the synchronous converter, in which the motor and generator windings are combined into one armature, with slip rings at one end and a commutator at the other and only one field frame. The result with either is AC-in, DC-out. With an M-G set, the DC can be considered to be separately generated from the AC; with a synchronous converter, in a certain sense it can be considered to be "mechanically rectified AC". Given the right auxiliary and control equipment, an M-G set or rotary converter can be "run backwards", converting DC to AC. Hence an inverter is an inverted converter.<sup>[4][5]</sup>

### Controlled rectifier inverters

Since early transistors were not available with sufficient voltage and current ratings for most inverter applications, it was the 1957 introduction of the thyristor or silicon-controlled rectifier (SCR) that initiated the transition to solid state inverter circuits.



The *commutation* requirements of SCRs are a key consideration in SCR circuit designs. SCRs do not turn off or *commutate* automatically when the gate control signal is shut off. They only turn off when the forward current is reduced to below the minimum holding current, which varies with each kind of SCR, through some external process. For SCRs connected to an AC power source, commutation occurs naturally every time the polarity of the source voltage reverses. SCRs connected to a DC power source usually require a means of forced commutation that forces the current to zero when commutation is required. The least complicated SCR circuits employ natural commutation rather than forced commutation. With the addition of forced commutation circuits, SCRs have been used in the types of inverter circuits described above.

In applications where inverters transfer power from a DC power source to an AC power source, it is possible to use AC-to-DC controlled rectifier circuits operating in the inversion mode. In the inversion mode, a controlled rectifier circuit operates as a line commutated inverter. This type of operation can be used in HVDC power transmission systems and in regenerative braking operation of motor control systems.

Another type of SCR inverter circuit is the current source input (CSI) inverter. A CSI inverter is the

dual of a six-step voltage source inverter. With a current source inverter, the DC power supply is configured as a current source rather than a voltage source. The inverter SCRs are switched in a six-step sequence to direct the current to a three-phase AC load as a stepped current waveform. CSI inverter commutation methods include load commutation and parallel capacitor commutation. With both methods, the input current regulation assists the commutation. With load commutation, the load is a synchronous motor operated at a leading power factor.

As they have become available in higher voltage and current ratings, semiconductors such as transistors or IGBTs that can be turned off by means of control signals have become the preferred switching components for use in inverter circuits.

### Rectifier and inverter pulse numbers

Rectifier circuits are often classified by the number of current pulses that flow to the DC side of the rectifier per cycle of AC input voltage. A single-phase half-wave rectifier is a one-pulse circuit and a single-phase full-wave rectifier is a two-pulse circuit. A three-phase half-wave rectifier is a three-pulse circuit and a three-phase full-wave rectifier is a six-pulse circuit.<sup>[6]</sup>

With three-phase rectifiers, two or more rectifiers are sometimes connected in series or parallel to obtain higher voltage or current ratings. The rectifier inputs are supplied from special transformers that provide phase shifted outputs. This has the effect of phase multiplication. Six phases are obtained from two transformers, twelve phases from three transformers and so on. The associated rectifier circuits are 12-pulse rectifiers, 18-pulse rectifiers and so on.

When controlled rectifier circuits are operated in the inversion mode, they would be classified by pulse number also. Rectifier circuits that have a higher pulse number have reduced harmonic content in the AC input current and reduced ripple in the DC output voltage. In the inversion mode, circuits that have a higher pulse number have lower harmonic content in the AC output voltage waveform.

### See also

- Solar inverter
- Distributed inverter architecture
- Grid tie inverter
- Inverter (air conditioning)
- Push-pull converter
- Static inverter plant
- Switched-mode power supply (SMPS)
- Space vector modulation
- Variable-frequency drive

### References

#### Citations

1. ^ <http://www.greentechmedia.com/articles/enphase-raises-15m-for-micro-inverters-1373.html>
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5. ^ Owen, Edward L. (January/February 1996). "Origins of the Inverter". *IEEE Industry Applications Magazine: History Department* (IEEE) 2 (1): 64–66. doi:10.1109/2943.476602.
6. ^ D. R. Graham and J. C. Hey, editors, ed. *SCR Manual* (Fifth ed.). Syracuse, N.Y. USA: General Electric. pp. 236–239.

## General references

- Bedford, B. D.; Hoft, R. G. et al. (1964). *Principles of Inverter Circuits*. New York: John Wiley & Sons, Inc.. ISBN 0-471-06134-4.
- Mazda, F. F. (1973). *Thyristor Control*. New York: Halsted Press Div. of John Wiley & Sons. ISBN 0-470-58116-6.

## External links

- Solar Panel Inverters explained in great detail.
- Sine Wave Versus Modified Sine Wave Power Inverter Video
- EFN.cn inverter manufacturer list: 170 companies with inverter power ranges, types, and contact information
- Virtual Synchronous Machine
- Notebook Inverter Schematic
- The Next Solar Frontier: Distributed Inverter Architecture

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